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THE ROMANCE OF THE DIAMOND.

BY SIR WILLIAM CROOKES, F.R.S.

FROM the earliest times, the diamond has fascinated mankind. It has been a perennial puzzle—one of the "riddles of the painful earth." Speculations as to the probable origin of the diamond have been greatly forwarded by patient research, and particularly by improved means of obtaining high temperatures, an advance we owe principally to the researches of Professor Moissan.

There is one theory of the origin of diamonds which appeals to the fancy. It is said that the diamond is a gift from Heaven, conveyed to earth in meteoric showers. The suggestion, I believe, was first broached by A. Meydendauer, who said:

> "The diamond can only be of cosmic origin, having fallen as a meteorite at later periods of the earth's formation. The available localities of the diamond contain the residues of not very compact meteoric masses, which may, perhaps, have fallen in prehistoric ages, and which have penetrated more or less deeply, according to the more or less resistant character of the surface where they fell. Their remains are crumbling away on exposure to the air and sun, and the rain has long ago washed away all prominent masses. The enclosed diamonds have remained scattered in the river-beds, while the fine, light matrix has been swept away."

According to this hypothesis, the so-called volcanic pipes peculiar to all diamond-mines are simply holes bored in the solid earth by the impact of monstrous meteors—the larger masses boring the holes, while the smaller masses, disintegrating in their fall, distributed diamonds broadcast.

Bizarre as such a theory appears, I am bound to admit that there are many circumstances which show that the notion of the Heavens raining diamonds is not impossible. The most striking confirmation of the meteoric theory comes from Arizona. Here, on a broad open plain, over an area about five miles in diameter, have been scattered one or two thousand masses of metallic iron, the fragments varying in weight from half a ton to a fraction of an ounce. There is little doubt that these masses formed part of a meteoric shower, although no record exists as to when the fall took place.

Curiously enough, near the centre, where most of the meteorites have been found, is a crater with raised edges three-quarters of a mile in diameter and about six hundred feet deep, bearing exactly the appearance which would be produced had a mighty mass of iron struck the ground and buried itself deep under the surface. Altogether, ten tons of this iron have been collected and specimens of the Cañon Diablo meteorite are in most collectors' cabinets.

An ardent mineralogist, the late Dr. Foote, cutting a section of this meteorite, found the tools were injured by something vastly harder than metallic iron. He examined the specimen chemically, and soon after announced to the scientific world that the Cañon Diablo meteorite contained black and transparent diamonds. This startling discovery was afterwards verified by Professors Moissan and Freidel; and Moissan, working on a piece of the Cañon Diablo meteorite, has recently found smooth black diamonds and transparent diamonds, in the form of octahedra with rounded edges, together with green hexagonal crystals of carbon silicide. The presence of carbon silicide in the meteorite shows that it must, at some time, have experienced the temperature of the electric furnace.

Under atmospheric influences the iron would rapidly oxidize and rust away, and the meteoric diamonds would be unaffected and left on the surface of the soil, to be found haphazard when oxidation had removed the last proof of their celestial origin. That there are still lumps of iron left in Arizona is merely due to the extreme dryness of the climate and the comparatively short time the iron has been on our planet. We are witnesses to the course of an event which may have happened in geologic times anywhere on the earth's surface.

Although in Arizona diamonds have fallen from the skies, confounding our senses, this descent of precious stones is what may be called a freak of Nature rather than a normal occurrence. To the average reader it is now known that there is no great difference between the composition of our earth and that of extraterrestrial masses. The mineral peridot is present in most meteorites. Yet no one doubts that peridot is also a true constituent of rocks formed on this earth. The spectroscope reveals that the elementary composition of the stars and the earth are pretty much the same. The spectroscope also shows that meteorites have as much of earth as of heaven in their composition. Indeed, not only are the selfsame elements present in meteorites, but they are combined in the same way to form the same minerals as in the crust of the earth.

It is certain from observations I have made, corroborated by experience gained in the laboratory, that iron at a high temperature and under great pressure—conditions existent at great depths below the surface of the earth—acts as the long-sought solvent for carbon, and will allow it to crystallize out in the form of diamond. But it is also certain, from the evidence afforded by the Arizona and other meteorites, that similar conditions have existed among bodies in space, and that on more than one occasion a meteorite freighted with jewels has fallen as a star from the sky.

Many circumstances point to the conclusion that the diamond of the chemist and the diamond of the mine are strangely akin as to origin. It is evident that the diamond has not been formed *in situ* in the blue ground where it is found. The genesis must have taken place at vast depths under enormous pressure. The explosion of large diamonds on coming to the surface shows extreme tension. More diamonds are found in fragments and splinters than in perfect crystals; and it is noteworthy that, although these splinters and fragments must be derived from the breaking up of a large crystal, yet in only one instance have pieces been found which could be fitted together; and these occurred at different levels. Does not this fact point to the conclusion that the blue ground is not their true matrix? Nature does not make fragments of crystals. As the edges of the crystals are still sharp and unabraded, the *locus* of formation cannot have been very distant from the present sites. There were probably many sites of crystallization differing in place and time, or we should not see such distinctive characters in the gems from different mines, nor indeed in diamonds from different parts of the same mine.

Although my experiments are chiefly connected with the physical and chemical properties of diamonds, and with researches on the perplexities of their probable formation, it will be a kind of compensation for some of my theories if I bring before the reader the general character of the South-African diamond-mines and their surroundings.

The most famous diamond-mines in the world are Kimberley, De Beers, Dutoitspan, Bulfontein and Wesselton. Kimberley is practically in the centre of the present diamond-producing area. The five diamond-mines are all contained in a precious circle three and one-half miles in diameter. They are irregular-shaped round or oval pipes, extending vertically downwards to unknown depths, and becoming narrower as the depth increases. They are considered to be volcanic necks filled from below with a heterogeneous mixture of fragments of surrounding rocks, and of older rocks, such as granite, mingled and cemented with a bluish-colored hard mass, in which famous "blue ground" the imbedded diamonds are hidden.

How the great pipes were originally formed it is hard to say. They were certainly not burst through in the ordinary manner of volcanic eruption, since the surrounding and enclosing walls show no signs of igneous action, and are not shattered or broken up even when touching the "blue ground." It is pretty certain that these pipes were filled from below after they were pierced, and the diamonds were formed at some previous time and mixed with a mud volcano, together with all kinds of débris eroded from the rocks through which it erupted, forming a geological "plum pudding." A more wildly heterogeneous mixture can hardly be found anywhere else on this globe.

It may be that each volcanic pipe is the vent for its own laboratory—a laboratory buried at vastly greater depths than we have yet reached—where the temperature is comparable with that of the electric furnace, where the pressure is fiercer than in our puny laboratories and the melting-point higher, where no oxygen is present, and where masses of liquid carbon have taken centuries, perhaps thousands of years, to cool to the solidifying-point.

In 1903 the Kimberley mine had reached a depth of 2,599 feet. Tunnels are driven from the various shafts at different levels, about 120 feet apart, to cross the mine from west to east. These tunnels are connected by two other tunnels running north and south. The scene belowground in the labyrinth of galleries is bewildering in its complexity, and very unlike the popular notion of a diamond-mine. All below is dirt, mud, grime; half-naked men dark as mahogany, lithe as athletes, dripping with perspiration, are seen in every direction, hammering, picking, shovelling, wheeling the trucks to and fro, keeping up a weird chant which rises in force and rhythm when a greater task calls for excessive muscular strain. The whole scene is more suggestive of a coal-mine than of a diamond-mine, and all this mighty organization—this strenuous expenditure of energy, this costly machinery, this ceaseless toil of skilled and black labor—goes on day and night, just to win a few stones wherewith to deck my lady's finger! All to gratify the vanity of woman! "And," I hear my fair reader remark, "the depravity of man!"

Prodigious diamonds are not so uncommon as is generally supposed. Diamonds weighing over an ounce (151.5 carats) are not unfrequent at Kimberley. I have seen in one parcel of stones eight perfect ounce crystals, and one inestimable stone weighing two ounces. The largest known diamond, the "Cullinan," was found in the New Premier Mine. It weighs no less than 3,025 carats, or 1.37 pounds avoirdupois. It is a fragment, probably less than half, of a distorted octahedral crystal. The other portions still await discovery by some fortunate miner.

At the close of the year 1904, ten tons of diamonds had come from these mines, valued at $300,000,000. This mass of blazing gems could be accommodated in a box five feet square and six feet high. The diamond has a peculiar lustre, and on the sorter's table it is impossible to mistake it for any other stone. It looks somewhat like clear gum arabic. From the sorting-room the stones are taken to the Diamond Office to be cleaned in acids and sorted into classes by the valuators, according to color and purity. It is a sight for Aladdin to behold the sorters at work. In the Kimberley treasure store the tables are literally heaped with stones won from the rough blue ground—stones of all sizes, purified, flashing and of inestimable price; stones coveted by men and women all the world over.

Where fabulous riches are concentrated into so small a bulk, it is not surprising that precautions against robbery are elaborate. The Illicit Diamond-Buying Laws are very stringent; and the searching, rendered easy by the "compounding" of the natives, is of the most drastic character. The value of stolen diamonds at one time reached nearly $5,000,000 a year. Now the safeguard against this is the "compound." This is a large square, about twenty acres, surrounded by rows of one-story buildings, divided into rooms holding about twenty natives each.

Within the enclosure is a store where the necessaries of life are supplied at a reduced price, and wood and water free. In the middle is a large swimming-bath with fresh water running through it. The rest of the space is devoted to games, dances, concerts and any other amusement the native mind can desire. In the compound are to be seen representatives of nearly all the picked types of African tribes. The clothing in the compound is diverse and original. Some of the men are evident dandies, whilst others think that in so hot a climate a bright-colored handkerchief or "a pair of spectacles and a smile" is as great a compliance with the requirements of civilization as can be expected.

One Sunday afternoon, my wife and I walked unattended about the compound, almost the only whites present among 1,700 natives. At one part a Kaffir was making a pair of trousers with a bright nickel-plated sewing-machine, in which he had invested his savings. Next to him, a "boy" was reading from the Testament in his own language to an attentive audience. In a corner, a party were engaged in cooking a savory mess in an iron pot; and, further on, the orchestra was tuning up, and Zulus were putting the finishing-touches to their toilet of feathers and beads. One group was intently watching a mysterious game. It is played by two sides, with stones and grooves and hollows in the ground, and appears to be of most absorbing interest. It seems to be universal throughout Africa; it is met with among the ruins of Zimbabwe, and signs of it are recorded on old Egyptian monuments.

A word as to the hardness of diamonds. They vary much in this respect; even different parts of the same crystal differ in their resistance to cutting and grinding. So hard is diamond in comparison to glass that a suitable splinter of diamond will plane curls off a glass plate as a carpenter's tool will plane shavings off a deal board. Another experiment that will illustrate its hardness is to place a diamond on the flattened end of a conical block of steel, and upon it bring another similar cone of steel. If I force them together with hydraulic power I can force the stone into the steel blocks without injuring the diamond in the least. The pressure which I have brought to bear in this experiment has been equal to 170 tons per square inch of diamond.

The only serious rival of the diamond in hardness is the metal tantalum. In an attempt to bore a hole through a plate of this metal, a diamond drill was used revolving at the rate of 5,000 revolutions per minute. This whirling force was continued ceaselessly for three days and nights, when it was found that only a small point, one-fourth of a millimetre deep, had been drilled, and it was a moot point which had suffered most damage, the diamond or the tantalum.

After exposure for some time to the sun, many diamonds glow in a dark room. One beautiful green diamond in my collection, when phosphorescing in a vacuum, gives almost as much light as a candle, and you can easily read by its rays. But the time has hardly come when we can use diamonds as domestic illuminants! Mrs. Kunz, wife of the well-known New York mineralogist, possesses perhaps the most remarkable of all phosphorescing diamonds. This prodigy diamond will phosphoresce in the dark for some minutes after being exposed to a small pocket electric light, and if rubbed on a piece of cloth a long streak of phosphorescence appears.

For the manufacture of a diamond, the first necessity is to select pure iron—free from sulphur, silicon, phosphorus, and so forth—and to pack it in a carbon crucible with pure charcoal from sugar. The crucible is then put into the body of the electric furnace, and a powerful arc formed close above it between carbon poles, utilizing a current of 700 amperes at 40 volts pressure. The iron rapidly melts and saturates itself with carbon. After a few minutes' heating to a temperature above 4,000° C.—a temperature at which the iron melts like wax and volatilizes in clouds—the current is stopped, and the dazzling fiery crucible is plunged beneath the surface of cold water, where it is held till it sinks below a red heat.

As is well known, iron increases in volume at the moment of passing from the liquid to the solid state. The sudden cooling solidifies the outer layer of iron and holds the inner molten mass in a tight grip. The expansion of the inner liquid on solidifying produces an enormous pressure, and under the stress of this pressure the dissolved carbon separates out in transparent forms

—minutely microscopic, it is true—but all the same veritable diamonds, with crystalline form and appearance, color, hardness and action on light the same as the natural gem.

Now commences the tedious part of the process. The metallic ingot is attacked with hot nitro-hydrochloric acid until no more iron is dissolved. The bulky residue consists chiefly of graphite, together with translucent chestnut-colored flakes of carbon, black opaque carbon as hard as diamonds—black diamonds, in fact—and a small portion of transparent colorless diamonds showing crystalline structure.

The residue is first heated for some hours with strong sulphuric acid at the boiling-point, with the cautious addition of powdered nitre. It is then well washed, and for two days allowed to soak in strong hydrofluoric acid in cold, then in boiling, acid. After this treatment the soft graphite disappears, and most, if not all, the silicon compounds have been destroyed.

Hot sulphuric acid is again applied to destroy the fluorides; and the residue, well washed, is attacked with a mixture of the strongest nitric acid and powdered potassium chlorate, kept warm —but not above 60° C., to avoid explosions. This treatment must be repeated six or eight times, when all the hard graphite will gradually be dissolved, and little else left but graphitic oxide, diamond and the harder carbonado or black diamond and boart. The residue is fused for an hour in fluorhydrate of fluoride of potassium, then boiled out in water, and again heated in sulphuric acid.

The well-washed grains which resist this energetic treatment are dried, carefully deposited on a slide and examined under the microscope. Although many fragments of crystals occur, it is remarkable I have never seen a complete crystal. All appear shattered, as if on being liberated from the intense pressure under which they were formed they burst asunder. I have singular evidence of this phenomenon. A fine piece of artificial diamond, carefully mounted by me on a microscopic slide, exploded during the night and covered the slide with fragments. This bursting paroxysm is not unknown at the Kimberley Diamond-mines.

William Crookes.